

**APPARATUS ADAPTED TO PERFORM AS COMPRESSOR, MOTOR, PUMP
AND INTERNAL COMBUSTION ENGINE.**

TECHANICAL FIELD:

This invention relates generally to a rotary apparatus, adapted to perform as compressor, pump, motor metering device or an internal combustion engine and more particularly to a radial vane type rotary fluid handling device characterized by two sleeves fitted with vanes such that they are independent of each other and relative motion between the vanes is used to achieve thermodynamic gas cycles.

OBJECTIVE OF THE INVENTION:

The objective here is to achieve a typical gas cycle as in conventional internal combustion engines, compressor etc, using parts described further

The parts and their arrangement in this apparatus is such that it is possible to achieve different gas cycles during its operation, by movement of a set of cam followers, timing device;

SUMMARY OF THE INVENTION:

A rotary apparatus, adapted to perform as, compressor, pump, motor, metering device or an internal combustion engine comprising of two identical vanes, two hollow cylindrical sleeves, hollow cylindrical liner, cams and associated linkages, couplings, shaft, clutch and braking arrangement; said vanes are fitted on to the curved surface of the sleeves, one vane on each sleeve, such that the vanes are radial to sleeve's curved surface and at one of the ends of each sleeve in such a way that half of the vane's surface protrudes out of the sleeve's end; and the said ends, fitted with vanes are placed adjacent, with the vanes angularly displaced so that said vanes are displaced from each other by a defined angle at all times; said sleeves so placed that their axis, the one passing through the center of their end surfaces, lay on one line; said curved surfaces where the vanes are attached on the sleeves, is such that it allows rotation of the adjacent vane and sleeve, about the said axis; a liner is provide; said liner along with the sleeve surface to form an enclosure; said liner's inner surface is contoured along the path traced by vane edge while rotating

about the said axis; said vanes divide the said enclosure formed inside the liner into two sealed chambers and enclosure is sealed from spaces outside the enclosure; said two sleeves, are coupled and uncoupled with a shaft by means of coupling arrangement actuated by came; said cams are placed on and, or driven by the sleeves; said cams actuate said braking arrangement such that each vane is held at a predetermined position alternately, and the vanes are free to rotate through an defined angle alternately; said cams allows both vanes to rotate simultaneously through an predefined angle and defines the angle by which the vanes are separated, rotated simultaneously or independently.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig 1- shows simplified fig. depicting elevation and side view of sleeve.

Fig 2- shows simplified fig. depicting elevation and side view of liner

Fig 3- shows simplified fig. depicting elevation and side view of the vane.

Fig 4- shows simplified fig. depicting the vane and sleeve fitting.

Fig 5- shows simplified fig. depicting liner, vane and sleeve assembly.

a) Liner

Fig 6- shows the simplified fig. depicting line diagram of liner, vane and sleeve.

Fig 7- shows the simplified fig. depicting v1 and v2 at initial position with an inclusive angle of 2α between them.

Fig 8- shows the simplified fig. depicting line diagram of initial movement of v1.

Fig 9- shows the simplified fig. depicting line diagram with v1 at position z.

Fig 10- shows the simplified fig. depicting line diagram with v1 and v2 at position Y and position X respectively.

Fig 11- shows the simplified fig. depicting v1 and v2 moving simultaneously from position Y and position Z respectively.

Fig 12- shows the simplified fig. depicting v2 and v1 at position Y and position X respectively(initial position).

Fig 13- shows simplified diagram depicting shaft placed in hollow annular space of the sleeve.

Fig 13a- shows a simplified diagram of the cams fitted on sleeves.

a) FL1- follower of cam C1.

b) FL2- follower of cam C2.

Fig 13b - shows line diagram of a typical vane positioning CAM.

Fig 14- shows the sliding friction clutch.

- a) SL – splines
- b) Fp - Friction pad

Fig 17 to Fig 23 - shows the various steps of apparatus working as single stroke IC engine.

- a) ExV - Exhaust valve
- b) SuV - Suction valve

Fig 24 to Fig 31 - shows the various steps when apparatus working as Two stroke IC engine.

- a) E1,E2- Exhaust Valves
- c) Su1,Su2- Suction valves

Fig 32 a- shows different view of cam operating suction valve and exhaust valve of single stroke IC engine.

- a) Pr – Profile
- b) Bc – Base circle

Fig 32 b – shows outline fig. of cams for operating valves and cams for positioning vanes, fitted on sleeve.

Fig 33 – shows different view of cam operating valves for two stroke engine.

- a) PrS – Profile for suction valve.
- b) PrE- Profile for exhaust valve

Fig 34– shows sleeve without depression.

- a) CSF - Curved surface

Fig 35 – shows sleeve with depression

- b) st – step on sleeve
- c) Flo- cooling fluid outlet hole.
- d) Rcf – receiving cone for sliding friction clutch.
- e) Fli- cooling fluid inlet line
- f) DPr – depression.

Fig 36 – shows vane

- a) stvs – strip to fit vane on sleeve
- b) Pis – Piston.
- c) Grps – groove for fitting piston rings.

Fig 37 – shows liner.

- a) SOH- split on outer half.
- b) PKV – pocket for valve.
- c) OH capital – Piter ja;f
- d) SIH – split on inner half.

DETAILED DESCRIPTION OF THE INVENTION:

Initially the parts, their arrangement and functions are described and depicted with the help of simplified geometric figures for easy perception and latter the machine parts are described in detail.

The basic parts are:-

1. Sleeve 2. Liner. Vane 4. Cams 5. Couplings

1) Sleeve

There are two numbers of sleeves. A hollow cylinder of outer diameter 'd' length 'l' and thickness 't' depicts these sleeves. Hereafter the two sleeves are referred as S1 and S2. The Sleeves are depicted in **fig.No 1**

2) Liner

The liner is depicted by hollow cylinder of inner diameter "D", length by "L" and thickness "T" with circular cover plates on both ends. The cover plates have a hole of diameter "d". (The hole diameter is same as that of sleeve's outer diameter). The liner is depicted in **fig.No 2**.

3) Vanes

There are two numbers of Vanes. The vanes are depicted by a rectangular plane of length 'L' and width 'r' such that $r = (D-d)/2$. Hereafter the two vanes are referred as V1 and V2. Shown in **fig.No.3**.

The half length of one edge (of length 'L') of V1, V2 is rigidly fixed on S1,S2 respectively, such that

- a) The plane (of surface) of V1, V2 is radial to S1,S2.
- b) V1, V2 are fitted on one of the two ends of S1,S2.
- c) Half length of fixed edge projects out of the sleeve end.

The V1, S1 fitting is here referred to as VS1, The V2, S2 fitting is here referred to as VS2

The Vane and Sleeve fitting is depicted in **fig.No.4**.

VS1 and VS2 are fitted in the liner, such that

- a) V1 and V2 are inside the liner,
- b) The three edges (other than the one fitted rigidly to sleeve) of both vanes, touch the inner surface of the liner,
- c) Half length of vane edge (the one projecting out of the sleeve ends) touch the outer curved surfaces of facing sleeve,
- d) The ends surfaces of the sleeves present inside the liner touch each other,
- e) Lengths of $(l-L/2)$ of both sleeves project out of the end cover plate holes of liner, and
- f) The axis passing through the center of the circular ends of liner, S1 and S2 is collinear. Hereafter this axis is referred as Central axis.

The line diagram of isometric view of liner, vane and sleeve fitting is depicted in **fig.No.5.**

VS1 and VS2 separate the space inside the liner into two parts. It is assumed that

- a) Both the spaces are isolated from each other and to the annular space of the sleeves i.e. no fluid can leak past from the sides of the vanes, nor through the end surfaces of the sleeves, touching each other inside the liner.
- b) The spaces inside the liner are isolated from the space outside the liner.

Hereafter the space on right side (clockwise side) of a vane is addressed as space ahead of vane; similarly the space on the left-hand side (counter clockwise side) of the vane is addressed as space behind of vane.

The simplified line diagram of side view of liner, VS1,VS2 fitting (with vanes depicted by radial lines) is depicted in **fig.No.6.**

The description of functioning of various components of the machine with help of simplified line diagrams of side view of liner with vanes (as in fig.No.6) is as follows.

Initial position

Initially V1,V2 are placed part by 2α degrees, such that]

- a) V1,V2 lie on either side of the vertical plane,
- b) The vertical plane bisects the inclusive angle between V1 and V2.

This Initial position of the V1 is hereafter referred to as 'POSITION X, and that of V2 as 'POSITION Y': the above mentioned is depicted in **fig.No.7.**

Now VS1 is rotated about its central axis in clockwise direction.

This leads to reduction of volume of space ahead of V1 and increase in volume of space behind V1, thus any gaseous fluid present in these spaces gets compressed and rarefied respectively. This compression and expansion form a part of the thermodynamic gas cycle. The above mentioned is depicted in fig.No.8.

As VS1 is rotated through $(360-4\alpha)$ degrees it is in a position, referred to as "POSITION Z" hereafter. On attaining this position both VS1 and VS2 are rotated. The same is depicted in fig.no.9.

When VS1,VS2 reach POSITION Y, POSITION X respectively, VS1 is stopped and VS2 continues to rotate.

The same is depicted in fig.No.10.

Like VS1, when VS2 attains POSITION Z, then both VS1 & VS2 are rotated till they attain POSITION X & POSITION Y respectively.

The same is depicted in fig.No.11 and No.12.

Now VS1 start's rotating and the full cycle is repeated.

On continuously rotating the vanes in this fashion, the two vanes are simultaneously at POSITION X, POSITION Y and POSITION X alternately, one in every 360-degree rotation of any of the two vanes. The vanes attaining initial position once in every rotation facilitates placement of accessories like injector, valves/ports, etc, at fixed, well defined points on the liner.

Heat is added to compressed gases trapped between vanes at POSITION X and POSITION Y.

The inclusive angle of 2α between V1 and V2 is of particular importance, as this is the minimum angle of separation between vanes at all times. (i.e. vane can only reach a position where it is at an angle of 2α from the other vane and not less than 2α). This angle of separation defines the compression ratio. By altering this angle, Compression ratio can be changed (with volume inside liner and sleeve's outside diameter, maintained constant)

By placing conventional suction (Intake), delivery (exhaust)/Valves, ports/Fuel Injector,(Spark Plug) at suitable points on the liner, the machine acts as compressor or internal combustion engine or motor.

The above-mentioned pattern of vane movements and a continual rotary output is achieved with help components, described below.

6) Shaft

7) Cams and associated linkages

8) Sliding friction clutch

9) brake bands

Shaft

The shaft is of length 'A' and diameter 'B' such that ' $A > 2 \times I$ ' and ' $B < \{d - t\}$ '. ('I', 'd', 't' are dimension's of the sleeve)

The shaft passes through the hollow annular space in the sleeves and protrudes out of the ends. It is depicted in **fig.No.13**.

Cams

Two no cams are used, one fitted on each sleeve.

The cams are concentric to the sleeve and its profile is negative and the profile ends makes an angle of 4α to the center. Cam fitted on S1,S2 are named as C1,C2 respectively. The plane bisecting the profile of C1 is parallel to the plane of the vane V1. Similarly the plane bisecting the profile of C2 is parallel to the plane of the vane V2. This shown in **fig.no.13a**.

The cam followers actuate linkages so as to engage and disengage the sleeves with the shaft. At the same time actuating brake bands to hold and release the sleeves. Description of cam operation follows. When V1 is at POSITION X the follower of C1 is just out of the profile, disengaging S2 from the shaft and engaging brake bands so as to hold S2 at rest. On V1 reaching POSITION Z, follower of c1 rides on the profile releasing brake band of S2 and engaging it with the shaft. Now both the sleeves rotate. As V2 brake band holds it stationary. At this point follower of C1 is at center of profile i.e. on line bisecting the profile. The process is repeated and desired movement of VS1 & VS2, as mentioned earlier, is achieved.

It is seen that the angle of profile defines the angle 2α degrees i.e. the minimum angle of separation of the vanes is equal to the angle that the beginning and end of profile makes to the center of the cam. This angle of profile if increased decreases the compression ratio and vice versa. The cam is so shaped that angle of the profile gradually increases and thus moving the cam follower along the central axis results in variation of compression ratio.

The cam is shown in fig.No.13b.

Sliding friction clutch

There are two sliding friction clutch. The clutches are fitted on the shaft, one on each of its ends. The friction clutch has slots on its inner diameter and makes sliding fit on similar splines on the shaft. The shape and features of sliding friction clutch are shown in fig.No.14

The sleeve end surface is conically shaped so as to receive the conical surface of sliding friction clutch i.e.the angle of cone (negative on sleeve and positive on sliding friction clutch) is equal. When the clutch is pressed by linkages, operated by cams, against the sleeve, the friction between sleeve and clutch surfaces engages the shaft and sleeve.

Brake bands

Brake bands or means of positive locking by means of conventional ratchet arrangement is used to keep the sleeve immobile when it is at rest.

The brake band is a strip with friction pad lining on its inner surface has a small working clearance from the surface of the sleeve. A lever against a spring force maintains the clearance.

Valves

The valves used are same as that used in conventional reciprocatory I.C. engines. Circles on the end cover plates of the liner depict the valves/ports.

The parts of this engine can be arranged so as to result in either a single stroke or a two-stroke engine.

a) Single stroke

There are two valves installed on the liner, one suction and one exhaust. They are angularly displaced by an angle of β . The exhaust valve lies in the space behind vane at POSITION X and ahead of vane at POSITION Y. The valves are opened and closed, so as to communicate the space inside the liner to space outside it. Linkages actuated by cams and its followers open them.

Step-1) Initially V1 and V2 are at POSITION X and POSITION Y. Please refer fig.No.17. The fig. also depicts the exhaust and suction valves installed on the liner. The suction and exhaust valves are in closed position.

Now V1 is rotated. The gases ahead of V1 gets compressed.

Step-2) As V1 reaches a position such that it makes an angle of θ to POSITION Z, the exhaust and suction valves open. This position of vane is referred as POSITION Z1 here after. The angle θ is such that the vane has rotated past the suction valve and space ahead of rotating vane is sealed from suction valve. Please refer fig.No.18.

Step-3) On V1 reaching POSITION Z the suction and discharge valves are closed. Please refer fig.No.19.

Step-4) Now both vanes rotate and V1 and V2 reach POSITION Y and POSITION X respectively. Please refer fig.No.20.

At this point heat is added to the compressed gas (similar to conventional I.C.engines). The injector/spark plug is placed on the liner between POSITION X and POSITION Y. Now V2 rotates. The gases behind V2 expand and ahead of V2 gets compressed. The expanding gases push V2. This is the power stroke for V2.

Step-S) As V2 reaches POSITION Z1 exhaust and suction valves open. Exhaust in space behind V2 is scavenged and fresh charge is introduced. Shown in fig.No.21.

StepR-6) This process takes places till V2 reaches POSITION Z and exhaust and suction valves are closed as shown in Fig.No.22.

Step-7) Now both V2, V1 rotate and reach POSITION Y, POSITION X respectively. This is the initial position. V2 is now put to rest. Heat addition to the compressed gases ahead of V2 takes place now. Please refer fig.No.23.

Now power stroke for V1 starts.

Now steps-1 to Step-7 repeats successively.

The position of valves with respect to vertical plane, the initial position of vanes, angles α and θ and volume of spaces inside the liner, are such that the compressed gas or combustible gaseous charge (compression and expansion is assumed to be adiabatic) can result in spontaneous ignition, either by self ignition or by spark as in conventional I.C. engines.

b) Two stroke

There are two valves, one suction and one exhaust installed on the liner. They are angularly displaced by an angle γ .

The suction valves lies in the space behind vane when the vane is at POSITION X.

space outside it. Linkages actuated by cams and its followers open them.

For each understanding of mechanism involved, two suction and two exhaust valves are shown in the fig. They are names Su1, Su2, E1, E2.

Step-1) Initially V1, V2 are at POSITION X, POSITION Y respectively. Please refer fig.No.24.

Now rotation of V1 is initiated, at the same time Su1 opens. All remaining valves are closed at this point. The vacuum created behind V1, due to its rotation, sucks in charge. The gas ahead of V1 gets compressed.

Step-2) As V1 reaches POSITION Z, SU 1 IS CLOSED. Shown in fig.No.25.

Step-3) Both V1, V2 now rotate and reach at POSITION Y, POSITION X respectively.

Heat is now added to compressed gases inside the liner. (Ignition of charge). V1 is now stopped and V2 rotates. This is the power stroke for V2 as shown in fig.No.26.

Step-4) As V2 rotates gas ahead of V2 gets compressed. V2 reaches POSITION Z as shown in Fig.No.27.

Step-5) Now both V2, V1 rotate, reach POSITION Y, POSITION X respectively. Heat is now added to compressed gas ahead of V2 (Ignition of charge). E2 is now opened as shown in Fig.No.28.

Now V1 is rotated and V2 is stationary. The gases behind V1 expand (power stroke for V1) and the gas ahead of V1 is expelled (heat rejection occurs).

Step-6) As V1 reaches POSITION Z, E2 closes. Shown in Fig.No.29.

Step-7) Both V1, V2 rotate to reach POSITION Y, POSITION X respectively. At this point E1 and Su2 opens. Now V1 stops and V2 rotates.

V2 now expels exhaust ahead of it and sucks new charge behind it as shown in Fig. No.30.

Step-8) When V2 reaches to POSITION Z, E1 and Su2 are now closed as shown in fig.No.31.

Step-9) Both V1 and V2 rotate and reach POSITION X and POSITION V respectively i.e. the initial position. Now step 1 to step 9 is repeated.

1. The volume inside the liner, minimum angle of separation if altered results in change of compression ratio.

In both type of above mentioned engines valves are opened and closed by linkages actuated by cams. As the valve function depends on vane position, individual Cams for each of the vane's is fitted on their respective sleeve or fitted on separate shafts, driven by its respective sleeve.

The cam for operating suction and exhaust valve of single stroke type engine is shown in fig.No.32a. The cam for operating suction and exhaust valve of two stroke type engine is shown in fig.No.33. The out line fig. of cams for operating valves and POSITION cams is shown in fig.no.32b.

Cams for single stroke engine

There are two cams, namely 'Ca 1' and "Ca 2' placed S 1 and S 2 respectively, Ca 1 actuate linkages for opening and closing suction and exhaust valves when V1 rotates. Ca 2 actuate linkages for opening and closing suction and exhaust valves when V2 rotates.

There are two profiles on each cam, axially displaced such that the path traced by a profile during its full rotation does not intersect or interfere, with that of the other profile.

The profiles makes an angle of theta to the center of the cam.

The followers of cams are so placed that when a vane reaches POSITION Z1, it begins to ride over the profile thus actuating valves. There are two similar cams, for operating fuel pumps.

Cams for two stroke engine

There are two cams, namely Cf1 and Cf2.

The cams are rigidly fixed on two shafts independent of each other. The shaft having Cf1 fitted on it is driven by S and shaft having Cf2 fitted on it is driven by S2. As it is observed that each valve is operated once every 720 degrees of rotation the shaft is driven at half the speed of that of the sleeves. There are two profiles on each of the two cams. There are two profiles on each cam, axially displaced such that the path traced by a profile during its full rotation does not intersect or interfere with that of the other profile.

The profile for such valve makes an angle of $(180-2\alpha)$ degrees to the center of the cam. If the follower is so placed that when the vane is vertical (i.e. at angle of alpha from POSITION X) the follower is angularly displaced by half alpha degrees from the beginning of the profile.

As the exhaust valve opens only after a vane undergoes power stroke and reaches POSITION V and it remains open till the vane is at that position, the profile is at $(180+\alpha)$ degrees from the end of the profile for suction valve. Please refer **fig. 33**.

There are two similar cams, for operating fuel pumps, placed on shaft having Cf1 and Cf2.

The detail description of parts now follows.

The parts, their fitting arrangement and exploded view of fittings are illustrated in fig.No.34 to Fig.No.51

SLEEVE

The sleeve as described earlier is a hollow cylinder, but has step of larger diameter at one of its ends. The end surface at the larger diameter end is curved such that it forms a quarter of a circular hollow ring. The other end surface is conically shaped, same as that of the sliding friction clutch. The curved surface at the larger end has two depression. A sleeve without depression is shown in fig.no.34 A sleeve with depression is shown in fig. No.35.

VANES

As previously described there are two vanes, rigidly fixed on the sleeves (one on each sleeve) and is required to rotate with the sleeve, inside the liner. As described earlier the vane while rotating is required to sweep the volume inside the liner.

It constitutes of a circular plate of diameter less than 'h'. It is attached to a strip which is to be rigidly fixed on to the sleeve's curved surfaced left uncovered by the liner. Two pistons with grooves are attached to the vane on the opposite sides of vane plate. Piston rings, same as those used in conventional I.C. engines, are fitted in the grooves. The piston rings press against the liner inner surface. Shown in fig.No. 36.

LINER

The liner is of the shape of a hollow circular quoit/ring (a pipe of circular cross section bent and its ends joined so as to form a hollow circular ring). The inner diameter of the liner hollow (the pipe diameter) is 'h'.

It is split in outer and inner halves for easy fitting and disassembly. The inner half is further split into two quarters. The outer half and inner quarters are further split.

The outer and inner halves have steps so as to make the inner surface overlapping at the ends. Thin polished strips are fitted at the interfaces which rub against each other during operation. The face to face contact of these strips seals of spaces inside the liner from spaces outside.

The ends are stepped, so as to make the ends overlapping. Clearance is provided at ends to make up for thermal expansion. The ends are made zig zag so that the piston rings (pressing against the inner surface of the liner) can smoothly pass over them during vane rotation. The liner is illustrated in fig.no.37.

A section of the liner is illustrated in fig. no. 38.

A section of the split ends is shown in fig. No.39.

One quarter of the liner fits on a sleeve and the outer surface of liner is flush with the curved surface of the sleeve's end face. The quarter portion of the liner that fits on the sleeve, covers the whole curved surface of the sleeve except a small strip where the vane is to be fitted. Liner and vane are fitted on the curved surface of the sleeve and the depression is fully covered by the liner. The depressions now form pockets for cooling fluid. The pockets are communicated to supply and return lines through holes in the sleeves.

The exploded isometric view of a sleeve and liner inner quarter fitting is illustrated in Fig.No.40.

The exploded isometric view of a sleeve, vane and liner inner quarter fitting is illustrated in fig.No.41.

The exploded isometric, view of two sleeves and liner inner quarter fitting, with vanes fitted in place is illustrated in Fig.No.42.

The isometric view of the sleeve, vane and liner inner quarter fitting is illustrated in fig.No.43.

The angular displacement between the radial plane of the grooves of a vane is such that rings fitted in them, press against the inner quarter of the liner, fitted on the same sleeve on which the vane is fitted i.e. the distance between the grooves of a vane fitted on a sleeve, is more than the width of the strip left uncovered by the liner inner quarter fitted on the sleeve.

The liner's outer half and inner quarters are flanged along the splitting lines. The flanges of inner quarter rest against corresponding surfaces of the sleeve. Dowel pins on the sleeve surface restrict the liner inner quarter from slipping during operation. The pins are provided only at one end leaving the other end free to expand during operation.

The liner's outer half is placed over the inner half and the former is enclosed in a casing. The casing is held together by fasteners at its flanges.

The flanges of the outer half are further extended to provide a flange parallel to the step on the sleeve.

These flanges are fitted with bolts so as to press a sliding ring against step on the sleeve. Thus pressing the two sleeves against each other. (Rollers can be provided at the sliding ring and sleeve interface to reduce friction).

The exploded isometric view of the outer half of liner and sliding ring, over the sleeve, vane and liner inner half fitting is shown in fig.No.44.

The exploded isometric view of the components in the previous fig. and the casing is shown in fig.No.45.

Illustrated in Fig.No.46 is isometric view of cam and valve operating cam fitting on the sleeve.

Illustrated in fig.No.47 is isometric view of complete vane assembly fitted on to sleeves with cams valve operating cams and fuel pump operating cam.

Illustrate in Fig.No.48 is top view of the machine, with two parts of liner outer half over the fitting shown in fig.no.47.

Illustrated in fig.No.49 is front view of components arrangement shown in previous fig. along with shaft and sliding friction clutch.

Illustrated in fig.No.50 is isometric view of machine with casing in place.

Illustrated in fig.No.51 is side view of the machine with shaft arranged as in two stroke engine.

ADVANTAGES

The rotary I.C. engine has many advantages

1. Compression ratio can be altered during operation by sliding of followers of cams.
2. There is no reversal of inertia forces.
3. It is possible to reverse the engine easily, that is angularly displacing the CAM profiles w.r.t. CAM followers thus eliminating gearing arrangements.
4. As the shaft is long the weight of the shaft by itself can serve the purpose of fly wheel.
5. The size of the engines is considerably smaller than conventional engines of same power output.
6. There is no need to maintain large lubricating oil slumps.
7. As the vanes are rigidly fixed to sleeve there is no slapping of vane, as is the case with pistons on liner in conventional I.C. engines. This results in reduced noise and vibration levels.